Principles of ACL graft fixation

Ph. Landreau
Aspetar
Doha
Qatar
Introduction

• The success of ACL surgery relies on patient selection, graft selection, fixation method, surgical technique (position, tensioning and surgical approach) and postoperative rehabilitation program.

• ACL graft fixation: major factor influencing the graft’s mechanical properties in the immediate postoperative period. ==> Physiotherapy timing and protocol.

• Industry

Numerous publications
ACL and Graft strength

Noyes 1984

• BTB = mean strength of 159 to 168 % of that of ACL.

• Estimation of the ACL in vivo loading during “normal activity,” on average, of 454 N.
Graft fixation

- Better mechanical properties on BPTB grafts fixed with interference screw than staples or sutures tied over buttons
- The fixation site is the weakest link of ACL reconstruction

A biomechanical comparison of different surgical techniques of graft fixation in anterior cruciate ligament reconstruction

MASAHIRO KUROSAKA,* MD, SHINICHI YOSHIYA, MD, AND JACK T. ANDRISH, M
1. Graft choice

2. Fixation choice

Biomechanical Properties of Selected ACL Graft Tissues

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Ultimate tensile load N (% ACL)</th>
<th>Stiffness (N/mm)</th>
<th>Cross-sectional area (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intact ACL</td>
<td>2160 (100%)</td>
<td>242</td>
<td>44</td>
</tr>
<tr>
<td>BTB 10 mm</td>
<td>2977 (138%)</td>
<td>620</td>
<td>35</td>
</tr>
<tr>
<td>Quadruple hamstring</td>
<td>4090 (189%)</td>
<td>776</td>
<td>53</td>
</tr>
<tr>
<td>Quadriceps tendon</td>
<td>2352 (109%)</td>
<td>463</td>
<td>62</td>
</tr>
</tbody>
</table>

West et al.

Fixation is the weakest link
Fixation Characteristics

- **Strength**: Load that causes permanent displacement of the graft fixation complex. Measured in newtons (N)

- **Stiffness**: Amount of strain or displacement produced by a given load. Measured in N/mm

- **Slippage**: Change in position of the initial graft fixation position at a specific number of submaximal load cycles
Strength: Activities of daily living and rehabilitation

- Minimum must be: 454 N (native ACL)

Characteristics of the fixation devices

Table 3
Failure Strength of Various Techniques of Graft Fixation

<table>
<thead>
<tr>
<th>Fixation</th>
<th>Ultimate Failure Load (N)</th>
<th>Stiffness (N/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patellar Tendon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal interference screw</td>
<td>558</td>
<td>—</td>
</tr>
<tr>
<td>Bioabsorbable interference screw</td>
<td>552</td>
<td>—</td>
</tr>
<tr>
<td>Soft Tissue (Femoral)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bone Mulch Screw (Arthrotek, Warsaw, IN)</td>
<td>1,112</td>
<td>115</td>
</tr>
<tr>
<td>EndoButton (Smith &amp; Nephew Endoscopy, Andover, MA)</td>
<td>1,086</td>
<td>79</td>
</tr>
<tr>
<td>RigidFix (Ethicon, Somerville, NJ)</td>
<td>868</td>
<td>77</td>
</tr>
<tr>
<td>SmartScrew ACL (Linvatec, Largo, FL)</td>
<td>794</td>
<td>96</td>
</tr>
<tr>
<td>BioScrew (Linvatec)</td>
<td>589</td>
<td>66</td>
</tr>
<tr>
<td>RCI Screw (Smith &amp; Nephew Endoscopy)</td>
<td>546</td>
<td>68</td>
</tr>
<tr>
<td>Soft Tissue (Tibial)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intrafix (Ethicon)</td>
<td>1,332</td>
<td>223</td>
</tr>
<tr>
<td>WasherLoc (Arthrotek)</td>
<td>975</td>
<td>87</td>
</tr>
<tr>
<td>Tandem spiked washer</td>
<td>769</td>
<td>69</td>
</tr>
<tr>
<td>SmartScrew ACL</td>
<td>665</td>
<td>115</td>
</tr>
<tr>
<td>BioScrew</td>
<td>612</td>
<td>91</td>
</tr>
<tr>
<td>SoftSilk (Acufex Microsurgical, Mansfield, MS)</td>
<td>471</td>
<td>61</td>
</tr>
</tbody>
</table>

Exceed the 450-N safe early physiological loading threshold proposed by Noyes et al.


Stiffness and Slippage

• **Stiffness:** Aperture fixation (joint line) > nonaperture (at distant site)


• **Slippage:** 6 weeks of activities of daily living corresponds to approximately 220,000 cycles to the ACL.

Graft fixation must be:

- **Strong** enough to avoid failure.
- **Stiff** enough to restore load displacement response and allow biological incorporation of the graft into the bone tunnels.
- Secure enough to resist slippage under cyclic loading (during the first 1 to 2 months when conversion from mechanical to biologic fixation is occurring).
Efficiency of Graft Fixation: Multifactorial

- Characteristics of the fixation devices
- Site of fixation (aperture or nonaperture)
- Density of the bone
- Tibia or Femur
- Type of graft
Site of fixation / Graft / Tunnel

- Direct
- Indirect
- Aperture
- Intratunnel
- Cortical

“Non anatomical
Semi-anatomical
Anatomical”

“Cancellous Cortical”
Graft tunnel motion

- 2 types of motion, longitudinal graft motion (bungee effect) and sagittal graft motion (windshield wiper effect)

- Direct/non direct fixation to bone

- Level of fixation (aperture or nonaperture)

- Tunnel enlargement multifactorial

Bone Mineral Density & Femur vs Tibia

• Bone dualenergy X-ray absorptiometry has shown that tibial metaphysis has a lower bone density compared to the femur.

• The force on the graft is in line with the tibial tunnel as opposed to the femoral tunnel.

Fixation at the tibial interface is the weakest link in the graft construct system.
BTB fixation: What you need to know.

- Bone plug healing: usually **6 weeks**.

- **Interference screw**

- **Transverse compression**

- **Transverse suspension**

- **Hybrid system**: compression and suspension

- **Press-fit**
BTB interference screws

- **Screw diameter:** Comparison in both tibial and femoral of 7 and 9 mm screws with a gap size of 1 mm show superior fixation with the 9 mm screw on both sides.

- It was recommended that 7 mm screws should not be used on the tibial side.

BTB interference screws

- **Screw length:** No significance

  No difference between screws which were 20 mm and 25 mm long.

  No significant difference in displacement, load to failure and stiffness (porcine) between interference screws of length 12.5, 15 and 20 mm.


BTB interference screws

- **Screw divergence**: Fixation by the interference screw is maximal at angles up to 10°.

- There is a significant reduction in tensile strength at angles over 20° (However, the mean pull-out strength remain at 497 N at 20°).


BTB interference screws

- **Bone mineral density**: most important variable that influences initial fixation strength and stiffness and resistance to slippage during cyclic loading.

- Higher in femoral tunnel than tibial tunnel.

- => **Larger screw diameter in tibial tunnel**.

- => **Anteromedial area of the tibia** = most acceptable.

A BMD of less than 0.6 g/cm² had a mean ultimate load to failure below 500 N
BTB interference screws

- Absorbable > Metal
  - Less hardware
  - Undistorted postoperative MRI
  - Decreased graft laceration
  - Easier revision surgery
- Absorbable < Metal
  - Reported foreign-body reactions
  - Potential for tunnel lysis
  - Breakage or drive failure during insertion

Metal or Bioabsorbable/Biocomposite: no significant difference in fixation strength and outcome.
BTB interference screws: Summary

- Relatively easy to use and inexpensive
- Provide aperture fixation
- Excellent stiffness
- Minimal slippage after cycling

- But potential screw laceration of either the bone plug suture or mostly the graft
Soft Tissue fixation: What you need to know.

• Soft tissue graft-bone integration: usually 6-12 weeks.

• Femur
  - Compression
  - Transfixion/Expansion
  - Suspension

• Tibia
  - Compression
  - Expansion
  - Cortical anchoring
  - Hybrid fixation
Soft Tissue fixation: Interference screws

- Can be used on the tibia and the femur, and both bioabsorbable and metal screws show similar biomechanical properties in fixation of soft-tissue grafts

- But lowest fixation strength, with significant slippage over time up to 5 mm


Soft Tissue fixation: Interference screws

- Femur: **Endopearl** device
- Tibia: backup **washers** or **staples**
- **Increasing** the diameter to 1 mm more than the tunnel and length of the screw
- **Compaction** drilling (Selby et al.)
- **Precise match** of the tunnel to the graft diameter (0,5 mm) (Steenlage et al.)
Soft Tissue fixation: Interference screws

- **Screw diameter**: Bigger is better for fixation! Indeed, using screws smaller than tunnel diameter increases the risk of graft slippage, while larger screws might lead to graft damage.

- → Hybrid fixation: Suspension/screw

- **Screw divergence**: < 20°
Soft Tissue fixation: Interference screws

- In contrast to bone plug fixation, metallic or bioabsorbable screws require greater lengths to adequately fix a soft tissue graft. On the tibial side, about 30 to 35 mm screws are recommended to achieve secure graft fixation.

- Bone mineral density.
Soft Tissue fixation: Alternative

- Femur

  - Suspension
  - Transfixion/Expansion
  - Compression
  + Hybrid system
Soft Tissue fixation: Alternative

- Tibia

- Compression

- Expansion

- Cortical anchoring

+ Hybrid system
Conclusion

• The ACL fixation method chosen should consider:
  
  • the immediate graft fixation strength and stiffness, according to the graft which is used,
  
  • the surgeon’s comfort,
  
  • the appropriate rehabilitation program,
  
  • the long-term clinical outcomes (potential future revision surgery).